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Article

BIM Adoption in the Cambodian Construction Industry: Key Drivers and Barriers

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Abstract: Critical issues surrounding the promotion and adoption of building information modeling (BIM) for construction projects are largely country-specific due to contextual socio-cultural, economic, and regulatory environments impacting construction operations and outcomes. There is little information on BIM adoption issues specific to the Cambodian construction industry ('the industry'). This paper aims to narrow existing knowledge by investigating key drivers for, and barriers to the adoption of BIM in the industry. Using descriptive survey method, feedback was received from contractors and architects that were registered with their respective trade and professional associations in the industry. The multi-attribute method and the Statistical Package for the Social Sciences (SPSS)-based Kendall's coefficient of concordance (W) test were used to analyze the empirical datasets. Results showed that out of the 13 significant drivers identified in the study, the most influential comprised the technology's ability to remarkably enhance project visualization and schedule performance; this is followed by awareness that the technology is redefining how project information is created and shared among stakeholders and therefore the future of the industry that cannot be ignored. On the other hand, the most constraining barrier to the adoption of the technology, out of 19 significant barriers, related to strong industry resistance to change, especially reluctance to change from 2D drafting to 3D modeling; other highly rated barriers included the high initial cost of the software and the shortage of professionals with BIM skills. Implementation of the study findings could support greater uptake of the technology and the leveraging of its key benefits to improving project success and the growth of the Cambodian construction industry, as well as those of other developing economies that share similar socio-cultural, economic, and regulatory environments.

Keywords: BIM; building information modeling; Cambodian construction industry; construction projects; project success

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1. Introduction

In the past decade, construction industry professionals and academics have centered much discussion on the potential offered by building information modeling (BIM) [1,2], to facilitating the achievement of construction project cost, time, and quality objectives, and improvement in the management of the project implementation process [3]. Numerous articles, books, and construction industry surveys have reported the general benefits, barriers, and limitations to BIM adoption throughout the entire lifecycle of various construction projects worldwide [4–6].

However, most studies on BIM implementation are related to construction operating environments of Western countries, with little consideration to contextual issues in the developing countries. To promote BIM in developing nations, it is important to identify the drivers of, and barriers to BIM implementation which are specifically applicable in developing nations.

Notwithstanding the growing number of studies that have investigated the barriers to, and drivers of BIM adoption and implementation, these are in the context of the Western countries [6–8]. There is still little research on the subject in the developing countries [9]. For instance, a review in a previous study [10] showed that out of the 135 developing countries identified by the World Bank, the number of BIM studies reported in China, Malaysia, and India were 13, 9, and 3, respectively, indicating a major research gap on the subject in the remaining 132 countries.

While issues around BIM adoption in developed countries may be homogenous on account of the relatively similar implementation standards, R&D expenditure, skills, and operating environments, corresponding issues in the developing countries are heterogenous [11], thereby requiring case-by-case exploration of the issues using adequate number of case studies. Moreover, increasing calls for more research on BIM adoption issues in the developing countries are driven by several other imperatives, such as the globalization of construction [12], increasing emphasis on the utilization of BIM and digital technologies for the implementation of major building and infrastructure projects in the developing economies by the World Bank, United Nations, and other global bodies [11], and the growing participation of multinational construction firms in landmark projects that require the utilization of BIM for optimized cost efficiency and goal effectiveness of the dollar investments in the projects within the developing economies [10].

This study contributes to narrowing the research gap by exploring BIM issues in Cambodia, with a view to contributing to providing an evidence base that could underpin further comparative studies of drivers to BIM adoption among architectural, engineering, and construction (AEC) firms in developing countries as suggested in recent studies [13]. It is hoped that the identified and prioritized BIM adoption barriers and enablers would constitute the 'external variables' that feed into the Technology Acceptance Model 3 (TAM3) with which the adoption intention and actual usage of BIM can be more reliably predicted—not only in Cambodia but also globally.

Overall, the study aimed to investigate the key issues unique to the Cambodian construction industry that are responsible for the prevailing slow rate of uptake of BIM, as well as the perceived benefits that could drive greater rate of uptake of the technology. To achieve the research aim, three research questions were posed to guide the research design and empirical data gathering as follows: (1) What key barriers inhibit greater rate of uptake of BIM in the Cambodian construction industry? (2) What perceived benefits and conditions could promote greater rate of uptake of the technology in the country? (3) How do the results of the study compare with those of related studies in other countries? It should be noted that, though they have not been fully utilized by stakeholders, the benefits of BIM have been clearly defined and reported by a number of academics [6,7]; by professional groups [8,14–17], as well as by software vendors [18,19]. Furthermore, the barriers, or challenges, to BIM implementation have been identified in numerous studies [9,12,20,21]. However, most of the reported drivers of, and barriers to BIM implementation are country-, industry-, and project-specific. This is due the fact that each project is unique and operated in different legislative, regulatory, and socio-cultural environments [11,22].

The Cambodian construction industry has grown rapidly in the past decade, mainly due to increased investment in infrastructure development and rapid urbanization, leading to new housing [23,24]. However, the construction industry in Cambodia, which is very fragmented and dominated by small-to-medium sized enterprises (SMEs), has been recording poor performance due to several reasons, such as poor safety [25], productivity [26], and sustainability [23] performance. In addition, it has been widely reported that successful implementation of BIM and other means of construction technology can help in improving the sector's performance [27,28]. With an aim to improve the sector's performance, the Cambodian government has introduced a "2015–2025 Industrial Development Plan" [29] for sectoral transformation from labor-intensive to technology-intensive. Given that the SMEs are responsible for the bulk of the outputs of the construction industry [30], implementation of the Cambodian government Industrial Development Plan for sectoral transformation through BIM implementation rests on the shoulders of the SMEs [31]. This responsibility, coupled with the developing status of Cambodia, could explain the extremely low level of BIM implementation by its construction industry to date. It is unsurprising then, that a review of the literature reveals an absence of studies on BIM in the Cambodian construction industry. This study is intended to narrow this gap in existing knowledge by exploring the main drivers of BIM implementation in Cambodia. The perceived barriers to BIM adoption are also investigated, as the awareness of the inherent barriers and challenges needs to be established as a precursor to BIM implementation [12]. The perceptions of key issues around BIM by contractors and architects—the lead role-players in the construction industry—are expected to assist Cambodia, as an emerging nation, to realize the potential offered by BIM towards the achievement of the government's Industrial Development Plan for the sectoral transformation.

2. Literature Review

2.1. Drivers/Benefits of BIM

Several studies have identified some benefits of BIM and the drivers for its implementation [3,9,20,32–36].

Ghaffarianhoseini, Tookey [6] viewed the range of BIM benefits as "technical superiority, interoperability capabilities, early building information capture, use throughout the building lifecycle, integrated procurement, improved cost control mechanisms, reduced conflict and project team benefits" (p. 2). Eastman, Eastman [34] identified: early design assessments ensuring that the project requirements are met; evaluation of building performance and maintainability by operations simulation; reliability of cost estimates, and reduction in variations as possible BIM benefits.

BIM improves productivity and facilitates the management of project information throughout the building lifecycle [20]. The collaborative benefits of BIM have also been investigated [3,37]. Furthermore, BIM contributes to increased productivity and efficiency [36], and contributes extensively to improved project value and enhanced construction practice [38].

A survey of nine of the world's top construction markets found that the top project-related benefits that contractors are receiving from BIM are reduced rework, reduced construction cost, reduced project duration, and improved safety, all of which impact strongly a company's return on investment [31]. Rodgers, Hosseini [39] identified drivers for BIM implementation including: enhancing collaboration on projects; earlier clash detection; increasing the ability to respond to requests for information; improving cost estimation and control abilities; increasing clients' satisfaction; enhancing product quality; increasing the quality of construction details; improving the ability to meet sustainability needs and facilitating cost savings during design. Thus, an in-depth review of related literature (e.g., journal articles, conference proceedings, and construction reports) was carried out in order to identify the most widely reported key drivers and benefits of BIM implementation; the findings are summarized in Table 1. Google Scholar was used a primary search tool to retrieve the studies (# = 107) on the subject, which were then reviewed to extract the most common drivers and barriers.

Table 1. Drivers/benefits of Building Information Modeling BIM.

Code	Drivers	References
D1	Adopting BIM provides a competitive advantage in the market	[6,9,39,40]
D2	There is a growing awareness of BIM	[5,9,21,33,41]
D3	BIM shortens the project timescale	[3,6,9,32]
D4	BIM reduces the overall project cost	[6,9,33,34,39]
D5	BIM improves construction productivity	[20,34,35,37,42]
D6	BIM improves construction safety performance	[1,5,6,40,43]

Table 1. *Cont.*

Code	Drivers	References
D7	BIM reduces construction waste	[3,6,35,38,42]
D8	BIM provides a more sustainable construction environment	[33,39,40,44]
D9	BIM is the future of project information	[6,9,32,38,39]
D10	BIM provides real time collaboration	[6,9,32,38,39]
D11	BIM increases coordination of construction documents	[6,9,32,38,39]
D12	BIM improves visualization	[6,9,12,32,35,38,39]
D13	BIM increases profitability	[6,9,32,38,39]

2.2. Barriers to BIM Implementation

Despite the purported benefits and drivers for BIM, its implementation to date has been limited, due to a number of challenges and barriers [12,20,21,45,46].

Gu and London [12] found that BIM awareness, knowledge, and interests vary across construction industry disciplines, but perceptions of the main factors affecting its implementation are consistent amongst engineers, architects, project managers, and other key stakeholders. Alreshidi, Mourshed [47] categorized BIM adoption barriers into five themes: socio-organizational barriers (e.g., risk avoidance and resistance to change); financial (e.g., cost of BIM training, software and hardware); technical (e.g., inter-operability issues); contractual (e.g., lack of BIM related aspects in current contracts), and legal (e.g., BIM model ownership, intellectual property, and copyright issues).

Won, Lee [21] undertook a review of literature on barriers to BIM adoption, and categorized them as three innovation constraining issues: company-specific innovation, inter-organizational innovation, and a hybrid of company-specific and inter-organizational innovation issues. The authors found that non-technical issues such as willingness to share information and effective collaboration among project participants were more significant as challenges to BIM implementation than technical issues such as BIM training programmes and technical support for inter-operability issues. Issues such as different attitudes and beliefs and cultural resistance of project participants are often cited [12,47], although some 'harder' factors are frequently mentioned, such as cost of investment and learning curve in BIM technologies, and poor software inter-operability [2,3,9,34,42]. Thus, insights gained from the literature on the most widely reported potential barriers to BIM implementation are summarized in Table 2.

Table 2. Potential barriers to BIM implementation.

Code	Barriers	References
B1	High initial cost of software and hardware	[9,40,46]
B2	High cost of training staff in new software and technology	[2,9,21,40]
B3	High cost of process and technology implementation	[2,21,34,40]
B4	Behavior (i.e., resistance, struggle) of professionals to change from drafting to modeling (i.e., change from current practices)	[12,34,40]
B5	Weak support from organization environment and culture in implementation of BIM	[2,20,21,34,40]
B6	Non-availability of support from top management in organizations for implementations of BIM	[2,20,21,34,40]
B7	Non-availability of skilled professionals	[2,20,21,34,40]
B8	Lack of BIM object libraries and standard modeling protocols	[2,6,21,34]
B9	Industry resistance to process change	[2,20,34,39,40]
B10	Lack of standardized process and guidelines for implementation of BIM in the construction industry	[2,12,21,40,46]
B11	Compatibility issue between software platforms	[2,12,21,40,46]
B12	Absence of inter-operable environment in the construction industry	[2,12,21,40]

Table 2. *Cont.*

Code	Barriers	References
B13	Limited use of BIM in construction industry	[2,21,46]
B14	Non-availability of market support/trends for BIM implementation	[2,12,21,40,46]
B15	Lack of comparative analysis between traditional and BIM-based project delivery methods	[6,39,40]
B16	Lack of comparative analysis between the existing methods and BIM technology in terms of cost utilized by organizations	[6,20,21,39,40]
B17	Non-availability of opportunities to apply the technology	[6,20,21,39,40]
B18	The industry is not clear enough on what BIM is yet	[6,20,21,39]
B19	Information models only work in the software they were made on	[6,20,39]

3. Research Method

This study adopted a descriptive survey research method because the empirical datasets were based on survey responses [48,49]; it is an appropriate research method to use where the questionnaire is the research instrument and the research data are measured on ordinal scale [50]. The empirical datasets comprised Likert scale (5 = strongly agree, 4 = agree, 3 = some-what agree, 2 = disagree and 1 = strongly disagree) rating responses on the relative levels of influence of the identified drivers and barriers of BIM adoption. The survey respondents comprised contractors registered with the Cambodia Constructors Association (CCA) and architects registered with the Cambodian Society of Architects (CSA). The selection of these groups of industry practitioners were based on their role as the lead decision makers in matters concerning the adoption, specification, and implementation of BIM on construction projects and the assessment of the performance [6,11,51].

Figure 1 highlight the five-stage methodological process followed in the study as recommended in previous studies [11,52].

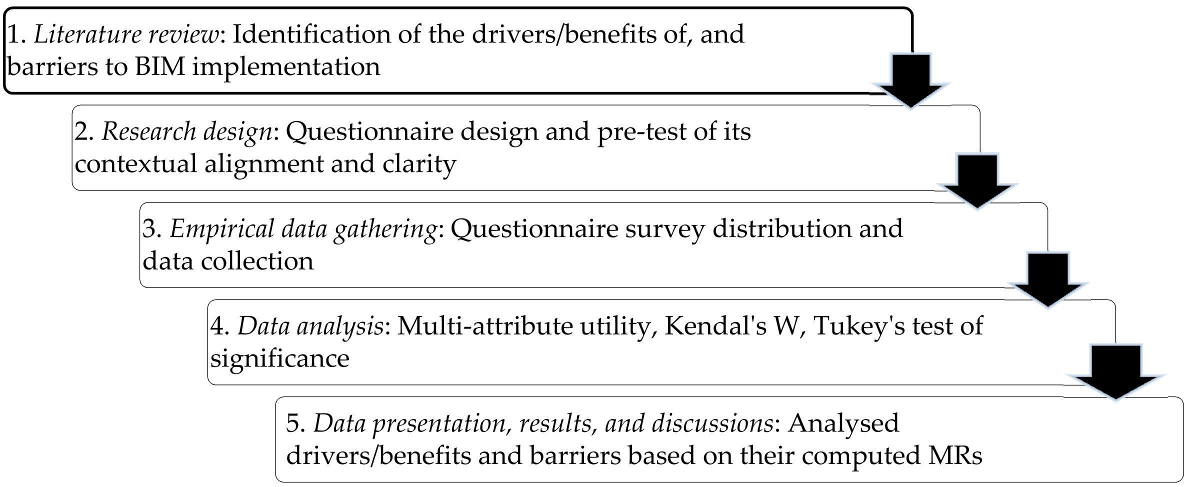

Figure 1. Methodological flow of the research process.

Given the dearth of local studies on the subject, the international contexts of the drivers and barriers of BIM gleaned from the literature were primarily utilized to design an open-ended questionnaire, which was subsequently used to obtain ratings of local industry practitioners as means of validation of the relevance of the identified constructs to the Cambodian context. Prior to the administration of the questionnaire, it was pre-tested for clarity, relevance, and completeness via face-to-face interviews with convenience samples of the practitioners which did not form part of the main surveys. The interviewees comprised two contractors with over 13 years of experience in local construction projects, two architects one of which was an award-winner for sustainable design, and an academic professor of architecture with expertise in BIM. The pre-test ensured that the questionnaire was contextually aligned, proofread for readability and clarity, and designed to enhance appeal and optimize response rate. The questionnaire comprised three sections: the first section elicited the respondents' demographic backgrounds; the second section sought rating responses on the relative levels of influence of the BIM adoption drivers identified through the literature; the third section sought respondents' feedback on the identified BIM adoption barriers. The open-ended sections of the questionnaire provided opportunity for the respondents to advise of additional drivers and barriers that were not included in the questionnaire. The questionnaires were hand-distributed to the pre-identified respondents, as this method enabled direct access to participants and ensured that the content was clear and that the respondents had the willingness and time to provide detailed answers to the questionnaire.

After the pre-test, 121 industry professionals, who previously signified interest to participate in further research during an earlier related study, were invited to participate in the questionnaire survey. The industry professionals comprised architects and contractors (one of the research limitations); their choice as the target populations for this study was based on their key role as the major influencers of the decision to adopt BIM in the design and execution of construction projects [26].

Data Analyses

Given the factor-prioritizing and agreement-seeking intent of the aim of the study, and the non-parametric or distribution-free nature of the empirical datasets, the multi-attribute utility (MAU) analysis and the Kendall's W test were found as the most suitable statistical methods for the data analysis [53,54].

The MAU analysis involved the computation of the mean rating (*MR*). The MR analysis focused on evaluating respondents' collective rating of a variable on the 5-point Likert rating scale used. As shown in Equation (1) [55], *MR* was computed as the sum of the product of each rating point (P) and the corresponding percentage response (*R*%) to the rating point, out of the total number of responses (TR) involved in the rating of the particular variable:

$$MR = \sum_{i=1}^{5} (P_i \times R_i\%), \tag{1}$$

where *MR* = mean rating; P_i = rating point i ($1 < i < 5$); $R_i\%$ = percentage response to rating point, *i*. Rank-ordering the *MR* values of variables in a given subset helped to prioritize the rated variables, with the variable having the highest *MR* value being the most influential or the most important in the subset.

To test the reliability of the survey instrument used and the consistency of the group responses, the Kendall's *W* test of concordance was carried out as the non-parametric equivalent of the multi-variate analysis of variance (MANOVA). The choice of Kendal's W as the appropriate test in place of the MANOVA parametric alternative was due to the ordinal rating scale of the survey instrument which produces distribution-free datasets that could not satisfy the assumptions of normality, skewness, and kurtosis required for MANOVA and other parametric analysis [53]. In carrying out the Kendall's W statistical test of significance of the respondents' agreement or disagreement on the rankings of the constructs, the null hypothesis was formulated to assume that the two respondents' group rating means and their associated ranks were not equal, overall. The alternative hypothesis assumed otherwise. Equation (2) [48] provides the expression for computing the Kendall's W coefficient:

$$W = \frac{12\sum_{i=1}^{n} \left(R_i - \overline{R}\right)^2}{m^2\left(n^3 - n\right)}, \tag{2}$$

where W = Kendall's W test static; $\overline{R}$ = mean value of the R_i ranks; R_i = total of each rank, rij, analyzed for each ith variable, out of the n variables being rated by the jth respondent out of the m groups of respondents ($1 < I < n$); i.e.,:

$$R_i = \sum_{j=1}^{m} r_i, j. \quad (3)$$

Further, the Tukey's post hoc tests were used to test the significance of the differences in each pair-wise comparison between the ranks analyzed from two respondent groups' mean ratings, while controlling the experiment-wise error rate [53]. Additionally, test of significance was carried out for the computed W against the null hypothesis. Previous studies [56], recommended the use of the F test to perform test of significance involving Kendall's W analysis where the number of rater groups, m, is small ($m < 20$) as was the case in this study. In this case, the F-test statistic was computed using Equation (4):

$$F = \frac{W(m-1)}{1-W}. \quad (4)$$

The F-test static computed using Equation (4) follows an F distribution with two degrees of freedom (df1 and df2): df1 = $n-1-(2/m)$ and df2 = $(m-1)$df1 [53]. Therefore, in the pair-wise rank comparisons and for the overall inter group rank comparisons, a conclusion of statistical evidence of no agreement was reached if the p-value associated with the computed F value was greater than the 0.05 alpha value used in the test; otherwise, the alternative conclusion was adopted. The SPSS nonparametric test for several related samples was used to run the analyses for greater accuracy in the results.

4. Results

4.1. Survey Responses and Respondents' Demographic Profiles

Out of the 121 industry professionals, who were invited to participate in the questionnaire survey, only 64 provided responses, resulting in 53% response rate. The remaining declined due to various reasons such as unavailability or lack of awareness or knowledge of BIM.

Of the 64 responses, the majority (i.e., 73%) were from contractors, while only 27% were from architects. Majority (i.e., 67%) had more than 10 years of construction experience in their current roles. The responses and the accompanying findings were therefore biased in favor of well-experienced contractors. Given the key role of the contractors as the main risk-bearers and coordinators of construction projects, the respondents' demographic profiles, though skewed, could be seen as evidence of quality and reliability of the inputs and findings of the study.

4.2. Drivers/Benefits of BIM

Table 3 summarizes the results of the Kendall's W and Tukey's post-hoc analyses of the rankings and the corresponding F values analyzed from the contractors' and architects' mean ratings for the identified drivers of BIM adoption.

Table 3. Mean ratings, ranking, pairwise, and inter-group comparisons of the significance of the differences in ranks for key drivers for BIM adoption.

Driver	All Respondents			Architects			Contractors			Tukey *F*	*W F*
	MR	Rank	SD	*MR*	Rank	SD	*MR*	Rank	SD		
D3	4.25	1	1.08	3.88	1	0.78	4.38	1	1.15	0.442 *	0.149 *
D12	4.23	2	1.08	3.82	2	0.73	4.38	1	1.15	0.262 *	
D9	4.13	3	1.15	3.59	4	1.00	4.32	2	1.14	0.980 *	
D1	4.02	4	0.72	3.71	3	0.69	4.13	4	0.71	0.344 *	
D10	4.02	4	1.27	3.35	8	1.37	4.26	3	1.15	0.194	
D5	3.94	5	1.05	3.59	4	1.06	4.06	6	1.03	0.149 *	

Table 3. *Cont.*

Driver	All Respondents			Architects			Contractors			Tukey *F*	*W F*
	MR	Rank	SD	*MR*	Rank	SD	*MR*	Rank	SD		
D7	3.92	6	1.29	3.41	7	1.12	4.11	5	1.31	0.912	
D8	3.92	6	1.19	3.35	8	0.86	4.13	4	1.23	0.406	
D11	3.92	6	1.15	3.53	5	1.01	4.06	6	1.17	0.829 *	
D2	3.73	7	0.76	3.29	9	0.59	3.89	7	0.76	0.972 *	
D6	3.66	8	1.12	3.47	6	1.01	3.72	8	1.16	0.876	
D4	3.45	9	1.07	3.47	6	1.01	3.45	9	1.10	0.900	
D13	3.42	10	0.92	3.53	5	0.62	3.38	10	1.01	0.336	

MR = Mean rating (Equation (1)); SD = Standard deviation; *W* = Kendall's *W* (Equation (2)); *F* = *F*-test statistic (Equation (4)); * (Significant at 0.05).

4.3. Barriers to BIM Implementation

Table 4 presents the results of the Kendall's W and Tukey's post-hoc analyses of the rankings and the associated *F* values analyzed from the contractors' and architects' mean ratings of the identified barriers to BIM adoption.

Table 4. Mean ratings, ranking, pairwise, and inter-group comparisons of the significance of the differences in ranks for key barriers to BIM adoption.

Barrier	All Respondents			Architects			Contractors			Tukey *F*	W *F*
	MR	Rank	SD	*MR*	Rank	SD	*MR*	Rank	SD		
B4	4.22	1	0.86	4.23	1	0.86	4.22	1	0.86	0.633 *	
B7	3.91	2	1.18	3.90	2	1.18	3.91	2	1.18	0.781 *	
B1	3.78	3	1.24	3.79	3	1.26	3.78	3	1.24	0.749 *	
B2	3.77	4	1.03	3.77	4	1.05	3.77	4	1.03	0.069 *	
B3	3.77	4	1.02	3.79	3	1.03	3.77	4	1.02	0.883 *	
B5	3.77	4	1.22	3.77	4	1.23	3.77	4	1.22	0.322 *	
B13	3.75	5	1.07	3.74	5	1.09	3.75	5	1.07	0.004 *	
B14	3.73	6	0.84	3.73	6	0.85	3.73	6	0.84	0.197 *	
B17	3.73	6	0.88	3.74	5	0.89	3.73	6	0.88	0.678 *	
B18	3.72	7	1.11	3.69	8	1.11	3.72	7	1.11	0.679 *	0.104 *
B8	3.70	8	1.08	3.71	7	1.09	3.70	8	1.08	0.07 *	
B12	3.64	9	1.06	3.65	9	1.07	3.64	9	1.06	0.006 *	
B6	3.52	10	1.13	3.52	10	1.14	3.52	10	1.13	0.053 *	
B10	3.50	11	1.01	3.48	11	1.00	3.50	11	1.01	0.195 *	
B9	3.27	12	0.91	3.26	12	0.92	3.27	12	0.91	0.077 *	
B11	3.20	13	0.86	3.19	13	0.87	3.20	13	0.86	0.18 *	
B16	3.17	14	1.18	3.13	14	1.17	3.17	14	1.18	0.301 *	
B15	3.05	15	1.10	3.02	15	1.11	3.05	15	1.10	0.815 *	
B19	2.72	16	1.79	2.71	16	1.82	2.72	16	1.79	0.004 *	

MR = Mean rating (Equation (1)); SD = Standard deviation; *W* = Kendall's *W* (Equation (2)); *F* = *F*-test statistic (Equation (4)); * (Significant at 0.05).

5. Discussion of Results

5.1. Key Drivers for BIM Implementation

Table 3 shows that in 7 of the 13 pair-wise comparisons, the *p*-values associated with the Tukey's post-hoc F-test statistic values for the analyzed W coefficients relating to the differences between the mean ratings of the contractors and those of the architects was higher than the 0.05 alpha value of the test. Therefore, there is no statistical evidence to accept the null hypothesis that assumed difference between the group rankings; consequently, the alternative hypothesis that assumed no difference between the rankings was accepted in the seven cases. In addition, the *p*-value of the F-test statistic for the overall Kendall's W coefficient analyzed for the difference between the ranks computed from the contractors' ratings and those of the architects showed a value greater than the 0.05 alpha used in the test. As a result, the alternative hypothesis that assumed no difference between the ranks computed for both groups were accepted. Discussions in Section 5.1 focus on the five highest ranking drivers based on the analyzed combined mean ratings of both groups; namely, "BIM reduces the project timescale" [D3]; "BIM improves visualization" [D12]; "BIM is the future of project information" [D9], "BIM provides real time collaboration" [D10], and "adopting BIM would give us a competitive advantage in the market" [D1].

With a mean rating value of 4.25, this was the overall highest-ranking driver of BIM implementation. This result agrees with a similar finding [41] that one of the key benefits of BIM is the ability to detect and eliminate errors and omissions at the most crucial early design stages, thus leading to an overall reduction in variations and cost overruns in projects. A similar study by Bryde, Broquetas [33] found that the use of BIM helped to shorten project timescale and was an influential driver for its adoption, particularly due to its ability to conduct early clash detection, resulting in minimization of associated delays and risks during on-site project implementations. Furthermore, BIM could prevent schedule delays, which enhances early completion and returns on investment [6,57].

With a mean rating (MR) of 4.23 in Table 3, "BIM improves visualization" [D12] was perceived as the second most influential driver for BIM adoption in the Cambodian construction industry. The ability to visualize complex concepts and gain better understanding of the building design and the utility it offers is one of the most desired design features, especially for the construction clients who know little about buildings and blueprint interpretation [21]. Ability to visualize the design can also bridge the gap between the design intent of the architects and how the designs are interpreted by contractors, thereby enhancing buildability [34]. Furthermore, 3D visualization improves decision making, and reduces inaccurate drawing interpretation, and drives efficiencies into business systems and processes by the collaborative nature of BIM [45]. In addition, visualization helps to manage client expectations, and enables a quick analysis of design alternatives during design reviews [41].

Ranked 3rd overall (MR = 4.13), BIM was widely perceived to enhance project information. In fact, feedback freely provided by one of the survey respondents in the open-ended section of the questionnaire read as follows:

> *"Operators within the industry are increasingly coming to terms with the fact that BIM is redefining how project information is created and shared among stakeholders. The technology is reshaping the future of the industry and can only be ignored at one's own risks".*

Eastman, Eastman [34] emphasized the benefit of BIM to clients, including the enhancement of project profitability through the improvement of project stakeholder information creation and sharing in each phase, whilst also decreasing the effort needed to produce that information. Contractors in particular find that BIM improves communication and access to information within the project team [58].

The joint 4th overall ranking of "BIM provides real time collaboration" (MR = 4.02) supports the assertion that BIM depends on a collaborative approach, with design changes being automatically updated and coordinated amongst the project team [59]. BIM provides a collaborative platform, providing smooth real-time updates to enable effective collaboration amongst team members [6]. The ability for contractors to collaborate more effectively with clients and designers is considered to be the leader among process-related BIM benefits [31,58].

The joint 4th overall ranking of "BIM provides competitive advantage" (MR = 4.02). For contractors, BIM provides differentiation from their competitors [9], by offering new services, which helps maintain repeat business [31]. BIM helps firms gain a competitive advantage through client recognition, and also by discovering and overcoming all the issues associated with BIM before competitors decide to implement it themselves [59]. Furthermore, competitive advantages in resource allocation and programming have been reported by contractors [58].

5.2. Key Barriers to BIM Implementation

Table 4 shows that in all 19 pair-wise comparisons, the *p*-values associated with the Tukey's post-hoc F-test statistic values for the analyzed W coefficients relating to the differences between the mean ratings of the contractors and those of the architects was higher than the 0.05 alpha value of the test. Therefore, there was no statistical evidence to accept the null hypothesis that assumed difference between the group rankings; consequently, the alternative hypothesis that assumed no difference between the rankings was accepted in all the 13 cases. Additionally, the *p*-value of the F-test statistic for the overall Kendall's W coefficient analyzed for the difference between the ranks computed from the contractors' ratings and those of the architects showed a value greater than the 0.05 alpha used in the test. As a result, the alternative hypothesis that assumed no difference between the ranks computed for both groups was accepted. There is therefore empirical evidence to conclude that there is consensus of opinions of the architects and contractors on the relative levels of influence on the identified barriers, both on the level of individual barrier rankings and at the level of overall group rankings. Discussions in Section 5.1 to Section 5.2 will focus on the six highest ranked barriers to BIM adoption based on the analyzed combined mean ratings of both groups; namely, "behavior of professionals to change from draughting to modeling (i.e., change from current practices)" [B4]; "non-availability of skilled professionals" [B7]; "high initial cost of software and hardware" [B1]; "high cost of training staff in new software and technology" [B2]; high cost of implementing the process and technology" [B3], and "weak support from organization environment and culture" [B5].

With a mean value (MR) of 4.22, this was the overall top ranked perceived barrier to BIM implementation. This lends support to the findings in Malaysia, where Gardezi, Shafiq [40] found this barrier to be significant. Furthermore, Gerges, Austin [46] found this to be the top ranked barrier by construction professionals in the Middle East. This may be due to developing countries' construction industries being at a more traditional stage of design coordination than in western countries, akin to BIM stage 1, which involves the migration from 2D to 3D object-based modeling, where the deliverables are mostly CAD-like [20]. Moreover, "structural BIM inequalities" persist, which lead to a resistance to move from traditional to BIM projects [6].

This was the 2nd ranked barrier (MR = 3.91), which lends support to the findings of Gardezi, Shafiq [40], Rogers, Chong [9], and Gerges, Austin [46], which all found that the lack of skilled personnel was a very significant barrier to BIM adoption. Indeed, the lack of experienced personnel in the use of BIM is very well documented in the literature (Sun et al., 2015).The situation in Cambodia could be seen as being similar to that of Malaysia, in respect of problems with the "caliber, capability, and quantity of human resources" [9].

This was the 3rd ranked barrier (MR = 3.78), which lends support to the findings of Eadie, Browne [42], Gardezi, Shafiq [40], Rogers, Chong [9], and Gerges, Austin [46], which all found that as typically BIM requires new software, and [at least] upgraded hardware, and as such, is considered to be a financial issue. This would be a significant barrier to BIM implementation in small-medium enterprises, and even more so in developing countries, such as Cambodia.

This was the joint 4th ranked barrier (MR = 3.70), which lends support to the findings of Khosrowshahi and Arayici [20], Eadie, Browne [42], and Gardezi, Shafiq [40], which all found that the high cost of BIM training was a financial disincentive to BIM implementation. Training and education in BIM, though, is seen as fundamental to the successful implementation of BIM, even though Rogers, Chong [9] regard the "down time" ensuing from individual and organizational learning to be a major cost of BIM implementation. Furthermore, set up costs with BIM is seen by some companies as being "the cost of doing business" [58].

Another joint 4th ranked barrier was found to be the high cost of implementing the processes and technologies associated with BIM, which lends support to the findings of Eastman, Eastman [34], Khosrowshahi and Arayici [20], and Gardezi, Shafiq [40]. However, in contrast to this, even though BIM shifts more design work towards the front end of a project, it is considered by some not to necessitate a complete change to business systems and processes [58], and some negative effects of the cost of BIM implementation are outweighed by the positive effects from updated processes [33].

Another joint 4th ranked barrier was found to be weak support from the organization environment and culture for BIM, which lends support to the findings of Khosrowshahi and Arayici [20], Won, Lee [21], Gardezi, Shafiq [40], Meyer and Thurnell [58], and Gerges, Austin [46]. Eadie, Browne [42] found that the scale of culture change to implement BIM was a very significant barrier, and cultural transformation is a far greater challenge than any technological challenge arising from BIM [59].

5.3. Implications for Further Esearch

The technology acceptance model (TAM) is a tried and tested analytical framework that is widely used in the ICT and social science research for exploring the acceptance and actual adoption of new technology—process, product or software [30]. The assumption—and a research hypothesis to be tested—is that the new technology has to be perceived to be usable and useful for the targeted users to accept it, incline strongly towards using it, and actually use it in their areas of operation [11]. Figure 2 presents the original TAM analytical framework as initially formulated [60] having five constructs—perceived ease of use, perceived usefulness, attitude toward using, behavioral intention to use, and actual technology use.

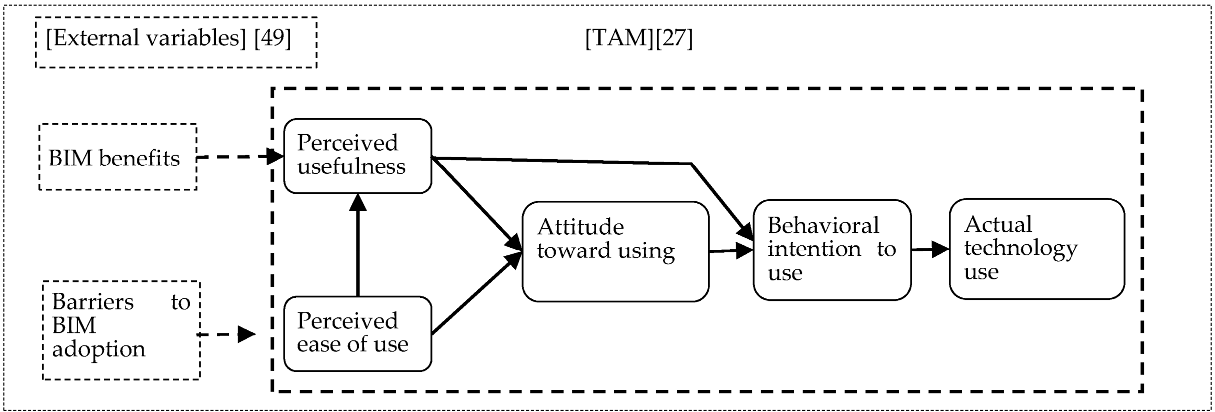

Figure 2. BIM benefits and barriers as external variables for a recommended further research on the impact of perceived usefulness and ease of use of the technology on its acceptance and actual use in the construction industry using the technology acceptance model [TAM].

This study has provided the external variables—BIM benefits and adoption barriers—for designing and implementing the TAM model in future research. Therefore, one of the key scientific contributions of the study is the initial phase identification and prioritization of the 'external variables' that feed into the TAM model with which the adoption intention and actual usage of BIM can be more reliably predicted—not only in Cambodia but elsewhere.

6. Conclusions and Recommendations

This study aimed at investigating the key drivers for and barriers to the adoption of BIM in the Cambodian construction industry. Results showed that out of the 13 significant drivers identified in the study, the most influential comprised the use of the technology for enhancing project visualization and schedule performance. On the other hand, out of the identified 19 barriers to the adoption of the technology, the most constraining related to strong industry resistance to change, especially reluctance to improve from 2D draughting to 3D modeling. Implementation of the study findings could support greater uptake of the technology and the leveraging of its key benefits to improving project success and the growth of the Cambodian construction industry, as well as those of other developing economies that share similar socio-cultural, economic, and regulatory environments.

Empirical datasets for this study were based on the responses provided by contractors and architects registered with their trade and professional associations in the Cambodian construction industry. Though the two groups of industry leaders have the greatest influence on the choice and implementation of BIM in projects [38], further studies are recommended to include feedback from other key stakeholders such as clients, engineers, and quantities to gain a holistic picture on the subject matter.

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